Upper critical magnetic field in Hybrid Rutheno-Cuprates

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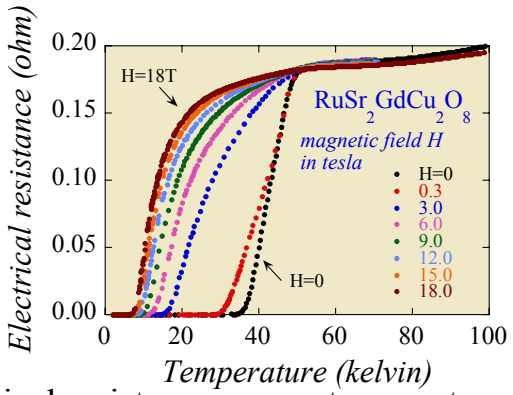
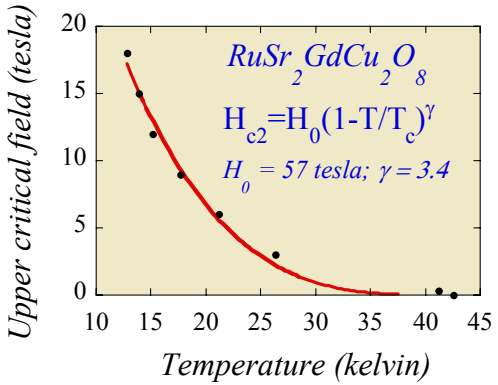
The zero-resistance state in superconducting materials at low temperatures can always be suppressed by a sufficiently large magnetic field. Here we study the effect of external magnetic fields up to 18 tesla in the superconductivity of $RuSr_2GdCu_2O_8$, and related materials. These are a remarkable ceramics, as superconducting and magnetic layers are stacked alternately in the crystalline structure. We found that superconductivity starts to be suppressed at a very fast rate in low fields, as the field is detrimental to the tunneling of electron-pairs between the grains of the material. However, superconductivity becomes much less sensitive to magnetic field, as the field increases in value.



Electrical resistance versus temperature in $RuSr_2GdCu_2O_8$ in various magnetic fields between 0 and 18 tesla. .



Upper critical field H_{c2} versus temperature in $RuSr_2GdCu_2O_8$.

Superconductivity is the ability displayed by certain materials at low temperatures, in which they carry electrical currents without any dissipation of energy. However, superconductivity can always be destroyed by sufficiently large magnetic fields. In addition to their elevated superconducting transition temperatures (T_c), the superconductivity in copper-oxide-based high-temperature superconductors (high-T_c) can be very resilient to magnetic fields, which makes these materials quite attractive not only for applications, but also for the physics involved in their behavior in high magnetic fields.

The rutheno-cuprates with composition $RuSr_2GdCu_2O_8$ and similar are quite remarkable, because superconducting layers made of copper-oxide planes are stacked alternately with magnetic layers, made of ruthenium-oxide planes. The measurement of the effect of intense magnetic fields on the superconductivity of these materials display very interesting behavior, as shown in the figures. The magnetic field shifts the onset of superconductivity to low temperatures at a fast rate in low fields, followed by a much slower rate in higher fields. The analysis of these data permits the development of new models leading to a better understanding of the superconductivity in these materials.

* The data shown in the figures was collected at the High National Magnetic Field Laboratory in Los Alamos.

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Education

Funding for this award facilitated the engagement of students Lee Harding (undergraduate) and Douglas Bird (graduate) in research. Both contributed to this work. All five students who took the condensed matter lab elective taught by the PI are pursuing or applying for graduate studies at SDSU and elsewhere.

Young minds playing with a ring-magnet levitated by an assembly of high-T_c superconductors. Picture from the *inner-space-outer-space* open-house.

Outreach

The PI and students developed *The Cool World of Cryogenics*, an exhibit with experiments using cryogenic materials. These experiments provide hands-on opportunities to the participants, and they brings out an enormous interest in science. The PI and students take this exhibit to high schools, and to campus open-houses.

Our main outreach activities are centered around "*The Cool World of Cryogenics" exhibit, which we show in high-schools and open-houses. The three main experiments are 1) the levitation of a ring magnet above an array of high-temperature superconductors cooled with liquid nitrogen; 2) the freezing of air-filled and helium-filled balloons in liquid nitrogen; and 3) the making (and tasting) of ice-cream using liquid nitrogen as a fast coolant. The level of the discussions can be adapted to the audience. The inner-space-outer-space open house of the College of Sciences gives us the opportunity of reaching a very large number of students (elementary through high-school), parents, and teachers. Our outreach activities with Morse High are noteworthy. This school is in a predominantly underrepresented area. Largely due to the excellence of their physics and other sciences programs, a significant number of students is college-bound.*